ASSESSING EYE GAZE PATTERNS BETWEEN INTERMEDIATE AND ADVANCED DESIGN SKETCHERS

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ABSTRACT

One difficulty with sketching pedagogy is the tendency to assess growth according to outcomes, as opposed to processes. We assessed eye gaze patterns between advanced and intermediate design sketchers and anticipated correlations between eye-gaze practices and sketching proficiency. Participants sketched two different objects using analogue materials, a potted plant from memory, and a MacBook from observation.

The study utilised Tobii 3 adjustable eye-tracking glasses and Tobii Pro data processing software. Twenty-five design sketching students and six design sketching instructors participated in the study.

Metrics measured include the quantity of reference line gazes, eye movement during line creation (targeting vs tracking), eye fixation duration, work checks per minute and subject gazes per minute.

The results show a difference in gaze patterns between intermediate and advanced sketchers, both in terms of practice and consistency. Eye-tracking sketching behaviours has revealed a new understanding of how teaching gaze habits could lead to improved methods of design sketching instruction.

Keywords: Creativity, Design education, Visualisation, Eye-Tracking, Industrial design

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1 INTRODUCTION

Sketching has held a dynamic role in society since man first shared their knowledge and experiences on cave walls and it continues to be an essential tool for communicating ideas in various disciplines and activities. Sketching has evolved from a simple recording mechanism for events and subjects (Rovida, 2012), to a representative skill that assists in designing everything from tools to buildings (Pipes, 2007). Eventually, sketching procured its own place in art, being a method of translation from mind to matter, letting viewers understand abstract thoughts through sketching (Bermingham, 2000) (Hoffman, 2020).

Technically, sketching translates mental images and experiences into visual representations and knowledge. Converting cognitive abstractions, visual cognizance and dimensional understanding into a communicative physical or digital drawing surface is a valuable part of many disciplines (Arnheim, 1993). The sketching process is a conversation between figurative and descriptive elements; it is a search for eventual coherence (Goldschmidt, 1991). Design, particularly industrial design and engineering, teaches this skill as a method for communicating ideas and objects in various perspectives for various purposes (Williford et al., 2020). The sketching process is evidence of visual reasoning, composed of three general segments: seeing, imagining, and performing (Park et al., 2007; 2009). Teaching students to create and share concepts effectively using these steps has been the regular endeavour of design instructors across the globe.

Sketching education is continuing to expand into new teachings, tools, and practices. The primary question is no longer concerning the accuracy of pen strokes or shading but more the accuracy of communication through a variety of tools and contexts. Students are taught to be adaptable and to complete similar tasks in digital and analogue environments (Christie, 2020). Additionally, in an effort to explore sketching education tools, there is new interest in the benefits of combining 3D and 2D drawing practices (Maycock, 2009). These studies attempt to dive deep into the sketching experience and personal psychology of those sketching. Our study explores similar avenues, investigating how people think and operate when learning how to sketch using new eye gaze measurement tools to influence future sketching instruction.

Within sketching pedagogy, there exists a tendency to assess growth according to outcomes, as opposed to processes, which limits educators' understanding of their students' comprehension of what is taught. In response, instructors have recently begun to explore the benefits of evaluating and teaching sketching techniques through alternative lenses and technologies (Gero et al., 2023; Williford et al., 2020; Rahimian, 2011; Kaul et al., 2016). In other disciplines, namely sports, marketing and user experience design, eye-tracking has already begun to dictate new ways of teaching and creating (Johnson, 2012; Bergstrom, 2014; Türkmen, 2022). Some researchers have discovered trends in skill-based tasks that can influence and indicate proficiency (Gonzalez, 2015).

Our study explores eye gaze tracking in the context of design sketching. We anticipated a correlation between eye-gaze practices and sketching proficiency, which led to the inclusion of both design students and sketching instructors as part of the study. However, we do not distinguish between students and instructors in the results, as we were more concerned with ranked outcomes. Other sketching studies assess qualities like creativity, but we will be more focused on process and outcome for the purpose of this study (Houzangbe, 2022). The observations and results from this experience shed light on previously undefined areas of sketching, including seeing and imagination (Park et al. 2007). Instead of instructing and assessing sketching practices based on external demonstrations and observations of students sketching and assessment of the outcomes, we can now record eye-gaze motion to understand how educators' and students' eye-gaze patterns differ. We expect this new knowledge will, when taught in drawing courses, improve imaginative and observational sketching education.

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2 METHOD

2.1 Participants

Twenty-five industrial design engineering students and six sketching instructors participated in the study. The group of design students consisted of thirteen females with a mean age of 21.7, who varied in age from 19 to 26, and twelve males with a mean age of 20.1, who ranged in age from 18 to 23. The group of sketching instructors consisted of six males with a mean age of 43.8, who varied in age from 37 to 53.

2.2 Eye-tracking tools

The study was performed with Tobii 3 adjustable eye-tracking glasses and Tobii Pro data processing software. The glasses are connected by wire cable to a Tobii battery and Wi-Fi computer. The cable was clipped to the participant's shirt to prevent it from interfering with the sketching exercise. The battery pack was clipped to the participant's belt or placed on a storage table next to the drawing table per their preference. Students who draw with prescription eyewear were asked to remove them for the study because the Tobii cameras struggle to track pupils accurately through prescription lenses. Participants focused on a small white card with a black dot in the centre of it to calibrate the glasses, which took a couple of seconds. Once calibrated, participants could begin the sketching tasks.

2.3 Setup

Students were invited to sign up for the study via advertisements placed near sketching rooms and recruiting efforts by sketching instructors during their classes. Sketching instructors were recruited individually, with six agreeing to participate. Each time slot was 30 minutes and took place in an empty sketching room at the Technical University of Delft. The study took place over three consecutive days. The setup for the study included one adjustable drawing desk and stool, a MacBook on an observation table and a divider separating the participant from the researchers. Materials included printed instructions, A4 drawing paper, black felt tip pens and 3 Copic Cool Gray markers with values of 3, 6 & 9. Participants were also asked to fill out a consent form alongside a short survey requesting their age, year in school, the number of sketching courses completed and perceived expertise in sketching.

After completing the survey and signing the consent form, eye-tracking hardware was placed on the participant. This process included explaining how the glasses function, with internal and external cameras, and then fitting them on participants by adjusting nose pads and straps for a secure fit, which took 2-3 minutes to complete. Once ready, participants were provided four sheets of A4 paper with instructions printed in the upper left corner for each of the four sketching tasks they were to complete. Each sheet also contained four light grey corner marks, placed 130mm apart in the centre of the page, indicating where the sketch should be drawn.

2.4 Sketching exercises

To conform with the 9-page requirement of this conference paper, only two of the four sketching tasks will be reported on. One task required participants to sketch from memory a cylindrical pot containing a plant with at least four leaves, combining geometric and organic shapes. Each sketch was to be completed with form and cast shadows. Another task required participants to sketch a MacBook laptop from observation, complete with form and cast a shadow. Examples of both tasks are shown in Figure 1. They were not restricted on time for each exercise, but all participants finished all four sketching exercises within the 30 minutes allotted.

The eye-tracking software recording eye movements could be seen live on a portable PC placed behind the divider, and researchers could monitor task progress and assess the recording accuracy of the tool while participants were sketching. If participants needed a new pen or had concerns, researchers responded to their needs. However, no additional information was given regarding the study prompts. Upon task completion, the eye-tracking hardware was removed, and participants were invited to review portions of their recordings. The physical drawings were kept and catalogued along with the digital records.

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Figure 1. Potted plant and MacBook sketching outcomes

2.5 Recording analysis

Researchers reviewed all Tobii Pro recordings multiple times and recorded data manually for targeted metrics. Metrics were determined through consensus as a research group after initial observation of the recordings.

3 RESULTS

All sketching results were ranked good, better and best rankings as assessed by two lead sketching instructors at TU Delft. Figures 2, 3, 4, and 5 show the eight lowest and highest-ranked sketching MacBook and Potted plant sketching tasks. When referring to "lower rank," we are referring to the eight sketching task outcomes that were least favoured during the assessment. The "higher ranked" refers to the eight most favoured outcomes. All metrics are explained in the first sketching exercise they appear in but will not be re-explained in follow on exercises. All metrics will be measured in each sketching exercise unless specified below. The gaze metrics in this study are as follows:

- Gaze quantity of reference lines
- Eye gaze movement during line creation: Targeting vs Tracking
- Eye gaze fixation duration
- Work checks per minute (potted plant only)
- Subject gazes per minute (MacBook only)

Figure 2. Lowest ranked Macbook sketch outcomes

Figure 3. Highest ranked MacBook sketch outcomes

Figure 4. Lowest ranked potted plant sketch outcomes

Figure 5. Highest ranked potted plant sketch outcomes

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3.1 Potted plant sketching exercise

3.1.1 Gaze quantity of reference lines

The quantity of gazes at reference lines while drawing the plant (organic) identifies the number of times participants gazed at reference lines or guidelines. These lines are made at the start of a sketch to help maintain perspective and form during the sketch.

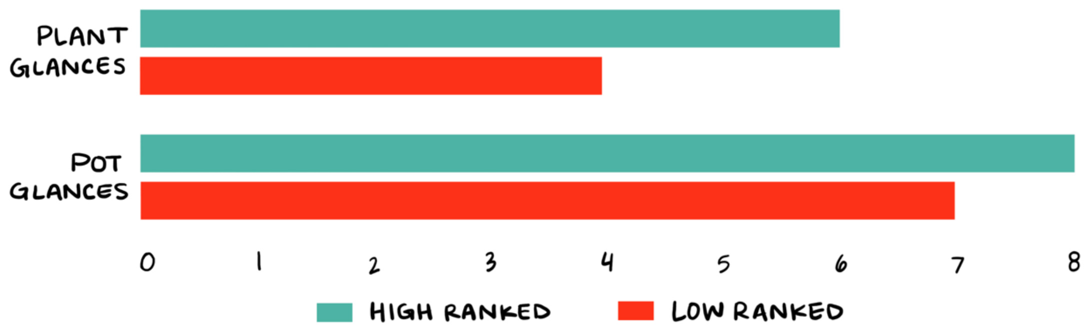

Figure 6, Average number of gazes at reference lines

The average number of times reference lines were gazed at during form construction by the lower group was four. In contrast, the higher group averaged six gazes. For the pot (geometric), the average number of gazes in the lower group was seven, while the higher group average was eight. See Figure 6.

3.1.2 Eye gaze movement during line creation: targeting vs tracking

Eye gaze refers to the location, focus time and motion of the participant's pupil while they sketch. Tracking refers to eye gaze that focuses on and follows the pen's tip during line creation. Targeting refers to eye gaze that precedes pen movement or line creation. See Figure 7.

Figure 7. Tracking and targeting

Gaze measurements for pen targeting and tracking while drawing the pot were the same for both higher and lower groups, with three participants targeting and five participants tracking. Pen targeting and tracking for the plant was again the same for both the higher and lower groups, but with five participants targeting and three tracking. See Figure 8.

Figure 8. Gaze during line creation tracking vs targeting

3.1.3 Eye fixation duration

Eye fixation duration refers to the time the eye gaze stays in one position without movement. Examples of measured duration times are shown in Figure 9, where the smaller red circle with a white outline in the left image indicates a shorter fixation time. In contrast, the right image shows a larger red circle indicating a longer fixation time.

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Figure 9. Eye fixation duration

Eye fixation measurements during the pots form construction for the lower group showed three participants had short fixations while five had long fixations. For the higher group, six participants had short fixations, while two had long fixations.

The lower group had two short fixations for the plant form construction, whereas six had long fixations. In comparison, the higher group had five short fixations and three long fixations. See Figure 10.

Figure 10. Eye fixation duration

3.1.4 Work checks per minute

Average work checks per minute refer to any time the participant had three surveying fixations of their sketch without drawing on the paper, inferring they were likely checking their work. The average work checks per minute almost correlate with rank directly, with more work checks per minute associating with higher ranked participants. See Figure 11.

The average work checks per minute for the higher group was 2.01, in comparison to the lower group, which had, on average, 1.8 work checks per minute.

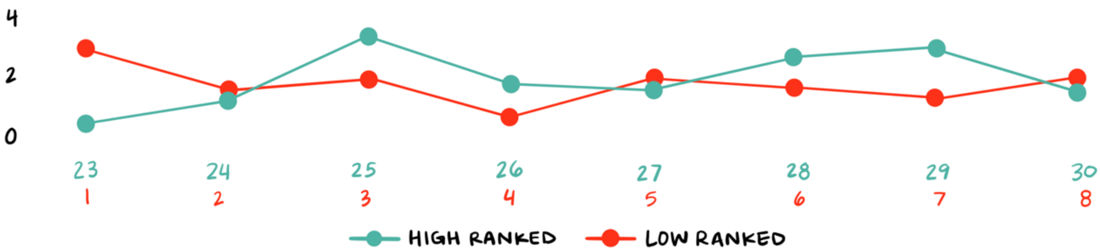

Figure 11. Work checks per minute

3.2 MacBook computer observation sketching exercise

3.2.1 Subject gazes per minute

Participants would pause their sketching and look up at the MacBook, removing their eyes from their sketch and paper to gaze at the MacBook. This was counted as a subject (or stimulus) gaze. Those whose drawings were ranked in the lower group exhibited a lower number of reference gazes per

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minute (GPM), with a high of nine gazes and a low of zero gazes. One participant never referenced the subject matter. Those participants in the higher group recorded a higher number of gazes per minute, with a high of 15 GPM and a low of nine GPM. See Figure 12.

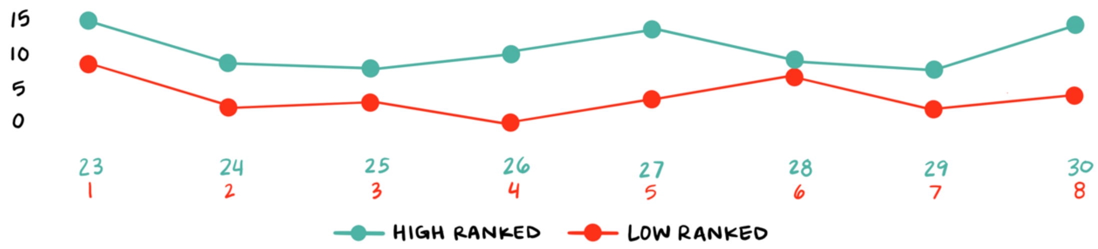

Figure 12. Subject gazes per minute

3.2.2 Eye gaze movement during line creation: targeting vs tracking

Seven participants from the lower group tracked their pen directly when creating their form lines, and one participant targeted their pen movement with their gaze. All eight participants' gazes of the higher group targeted their pen strokes. See Figure 13.

Figure 13. Eye gaze movement during line creation

3.2.3 Eye fixation duration

Eye fixation duration during cast shadow construction showed seven of the lowest-ranking participants exhibited long fixations, while only one participant had short fixations. Five of the highest eight exhibited long fixations, and three exhibited short fixations.

Eye fixation duration during form shadow construction indicated six out of the eight lowest-ranking participants exhibited long fixations, while two participants had short fixations. Five of the highest eight showed long fixations, and three revealed short fixations.

Eye fixation duration during form outline construction showed seven out of the eight lowest-ranking participants exhibited short fixations, with one showing long fixations. Four of the highest eight exhibited short fixations, while four held long fixations. These results are combined in Figure 14.

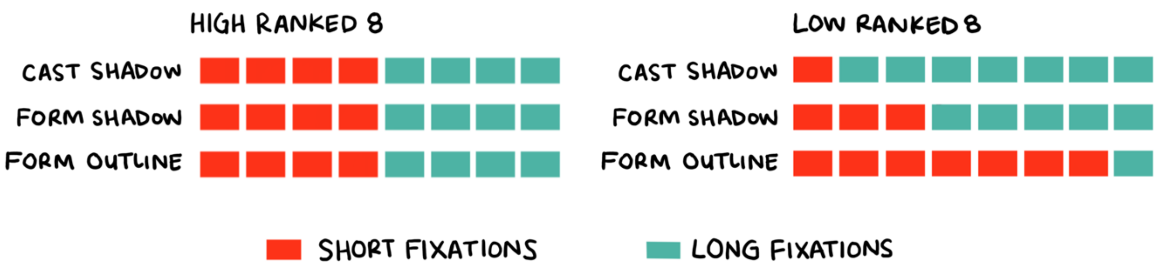

Figure 14. Eye fixation duration

4 DISCUSSION

We acknowledge that the sample size for this study is not statistically viable but provides enough positive outcomes to encourage further research and exploration.

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4.1.1 Participant comfort and biometric data collection

The nature of this experiment contained several elements that could have impacted the performance of the participants. Wearing eye-tracking glasses caused concern for some participants, who acknowledged that their private gazes were being exposed for the first time. To have one's eyesight watched and analysed was observed to be temporarily uncomfortable for some of the participants. Additionally, consistency in eye movements between exercises, or the lack thereof, can possibly be explained by the ability to warm up to sketching over time. It can be assumed that the participants' confidence increased over the course of the four drawings.

It is also worth acknowledging that adjustments to the drawing table angle and height and the drawing stool height were only performed by a few of the sketching instructors. None of the student participants adjusted their drawing furniture. We do not know if participants would have made adjustments outside of a study setting, which might have influenced sketching performance.

Lastly, future studies may explore other biometric measurements like brain waves, blood-oxygen levels, and heart rate. Each has the potential to provide insights into sketching practices, but will also affect participant comfort, which will have to be taken into account.

4.1.2 Target vs tracking

In reviewing the data from the two exercises, it can be observed that higher-ranking groups tend to target their gaze and pen motion when sketching from observation (Fig. 13). However, in contrast, most high and low-ranked participants tracked when drawing the pot (geometric object) and targeted when drawing the plant (organic object) (Fig. 8). This behaviour difference in the same sketching exercises should be explored further. Ultimately, one conclusion from observation may be that focusing on endpoints during line creation and centre points during ellipse creation can lead to more consistent and better-ranked outcomes, particularly in the context of observational sketching.

Targeting is common among readers, gamers, and musicians, suggesting that the individual is thinking or planning ahead, particularly when trying to replicate an object or fulfil a prescribed task. This could indicate more intention in line creation for higher-skilled sketchers. Having students watch videos of these different practices might help them improve their sketching outcomes.

4.1.3 Fixation durations

Initially, fixation measurement indicated that long fixations pointed to increased confidence or competence in sketching; however, after assessing the data, that may not be the only possibility. There is little relationship between ranking and long fixations, but we see there might be a relationship between consistency and ranking. The ratio of highly ranked participants is stable between sections of each exercise (Fig. 10, 14), while lower ranked participants are less consistent throughout each exercise. The implication is that as sketchers progress, they build confidence in their unique sketching processes through practice.

Other fixation results show an increase in long fixations among the lower-ranking groups as they switched from sketching the form outline to sketching shadows. This difference could be due to a change in sketching tools, going from pen to marker. It could also be due to the change in sketching tasks, switching from creating an outline to filling in the outline. Once the outline has been made, completing the shadow is a less creative endeavour. This idea is reflected in changes in eye fixation patterns, stroke patterns and overall performance (Fig. 10, 14).

The pot and plant again showed unexpected results. Higher-ranked participants had shorter fixations while drawing the pot and the plant, and lower-ranked participants had longer fixations while drawing the pot and the plant (Fig. 10). This could indicate that eye fixation duration might not be significant when drawing organic and geometric objects in the same composition. However, extended eye fixation duration might help indicate skill level.

4.1.4 Work checks

Exercises incorporating more elementary forms like cylinders exhibit similar average work checks between the lowest and highest-ranked groups. Exercises that require observation or organic forms

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generally have a wider gap between average work checks, with higher-ranked groups typically gazing at their work more (Fig. 11, 12). The implication of this finding could be that better sketchers tend to shift their efforts away from elementary construction and towards more difficult parts of an exercise. In other words, participants that ranked best checked their work more frequently when drawing the MacBook, which was not as basic as the potted plant exercise. Lower-ranked participants still checked their work but significantly less when presented with uncommon tasks. If instructors emphasised checking and rechecking work consistently across exercises, perhaps it could increase student abilities to transition into more complex sketching areas.

4.1.5 Discrepancy between observation and outcome

We saw a discrepancy between what participants viewed or looked at and what they sketched in the observation exercise. For example, the MacBook was open in front of the sketcher, and based on recorded eye fixations from the sketcher's point of view, there was a roughly straight line between the lid and the base, showing no angle between the top and bottom planes. Yet the participant would draw the MacBook with a significant angle. There seems to be a cognitive translation between what the eye sees and how the brain interprets what they see. Lower-ranked participants extensively reinterpreted what they saw into a mental image and then sketched the mental re-creation of the object rather than what they observed. Thus, what is sketched on paper often never reflects what is observed. However, those that had higher levels of subject gazes per minute tended to create a closer representation of reality than those with lower levels (Fig. 12).

5 CONCLUSION

In this study, we explored eye gaze differences between advanced and intermediate industrial design students' eye behaviour while they sketched particular objects. The results generally show a difference in gaze patterns between intermediate and advanced sketchers, which reinforces our hypothesis. By comparing the various exercises, we found higher ranked participants target rather than track line creations, have more consistent fixations, review their work more often and have better observational skills. Although we acknowledge the limited sample size of this study, it can be deduced that eye-tracking has opened a new understanding of how gaze behaviour can lead to improved methods of design sketching instruction in the future.

The next steps will be to develop material based on these findings that instructors can use to inform the way they teach sketching, particularly in foundational courses. Acknowledging additional parts of the sketching process can lead to more diversity in educational contexts, while also making sketching more accessible and refined as a taught skill in industrial design. Eye-tracking in sketching allows professors to learn and teach not only from outcome and observation, but through actual knowledge of how people see and act simultaneously.

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